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Nitrate Poisoning and Feeding Nitrate Feeds to Livestock

Introduction

While nitrates (NO_3) are not very toxic, nitrites (NO_2) are toxic. In ruminant animals such as cattle, sheep and goats, nitrate is converted to nitrite by bacteria in the rumen. This nitrite is then changed to ammonia. Excess ammonia is absorbed by the blood and passed in the urine as urea. This occurs when the nitrate breakdown system is in balance and no surplus of nitrites accumulate. Refer to Figure 1.

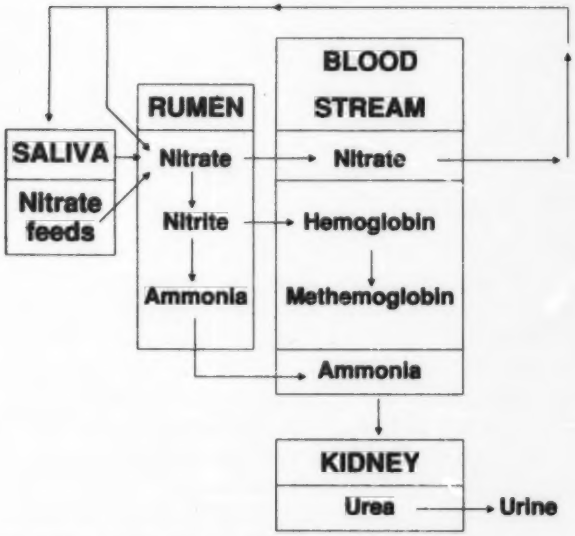

Figure 1. Nitrate pathway in ruminants

In contrast, monogastric animals such as horses and pigs, convert nitrate to nitrite in the intestine, closer to the end of the digestive tract, where there is less opportunity for the nitrites to be absorbed by the blood. It is this difference in the site of conversion that makes nitrate poisoning of much less concern for monogastric animals than it is with ruminants.

When ruminants consume a high nitrate feed, some of the nitrate cannot be immediately converted to nitrite and finally to ammonia. This causes both nitrate and nitrite to accumulate in the rumen. Nitrate is continually being released from the feed being digested in the rumen. The addition of new nitrate into the rumen intensifies the problem.

Nitrate poisoning occurs when the nitrite level in the rumen exceeds the capacity of the microbes to convert it to ammonia. When this happens, nitrate and nitrite are absorbed through the rumen wall into the bloodstream. It is the nitrite that causes toxicity. Nitrite combines with hemoglobin to form methemoglobin. Hemoglobin carries oxygen to body tissues while methemoglobin is unable to do so. When enough hemoglobin is converted to methemoglobin the animal begins to suffer from oxygen starvation. The change in the hemoglobin (red blood cells) is influenced by:

- rate of nitrate intake (amount of feed and how quickly it is consumed)
- rate of conversion of nitrite to ammonia in the rumen
- rate of digestion of feeds and the subsequent release of nitrates
- movement of nitrite (feed passage rate) out of the rumen.

Nitrate that is transported into the bloodstream does not create the initial problem, but can be recycled back into the rumen via saliva or intestinal secretions. Nitrate that is recycled and returned to the rumen can be converted to nitrite and then reabsorbed back into the bloodstream, therefore intensifying the problem.

The amount of nitrate being recycled back into the rumen along with the rate of nitrite breakdown influences what the toxic nitrate level is for different animals. Individual animals have different levels of tolerance to nitrites because of the breakdown and recycling rates. This is reflected in the variability between animals in the amount of methemoglobin that can form before production or reproduction is affected, or death occurs.

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Chronic nitrate toxicity

Chronic nitrate toxicity is a form of nitrate poisoning where the clinical signs of the disease are not observed. It is more common to see a reduction in weight gain, lower milk production, depressed appetite, and a greater susceptibility to infections. These production related problems or lossses are not often recognized and will occur when nitrate levels are at 0.5 to 1.0 per cent of the feed consumed (on a dry basis).

Chronic nitrate poisoning can cause abortions to occur within the first 100 days of pregnancy because nitrates interfere with the implantation of the egg in the uterus. When implantation does not occur, the fetus dies and is reabsorbed by the cow. During the first trimester of pregnancy, no obvious signs of an abortion are seen. Reproductive problems may also occur due to a nitrate or nitrite induced hormone imbalance, but most are usually not recognized as feed related.

Calves affected by nitrate poisoning in the last three months of gestation are usually born one to four weeks premature, and most appear normal but die within 18 to 24 hours of birth. Newborn calves that survive, but are affected by nitrate poisoning, may have convulsions and seizures.

Acute poisoning

With acute poisoning the signs of poisoning are observed and the animal is in critical condition. Nitrate is rapidly converted to nitrite in the rumen and is immediately absorbed in large amounts into the bloodstream. Animals can die within a few hours of initial ingestion of a high nitrate feed.

If cattle are fed once a day, maximum methemoglobin levels occur approximately eight hours after feeding. When cattle are fed twice daily, maximum levels occur four to five hours after feeding. The once a day feeding program results in higher total methemoglobin levels than twice a day feeding. With a once a day feeding, a larger quantity of feed is consumed at once and a greater amount of nitrate is released from the feed in a short period of time.

Signs of acute poisoning in cattle are: increased heart rate, muscle tremors, vomiting, weakness, blue-grey mucous membranes, excess saliva and tear production, depression, labored or violent breathing, staggered gait, frequent urination, low body temperature, disorientation and an inability to get up. Animals are often found in a lying position after a short struggle. In most cases of acute poisoning, animals are found dead before any signs of toxicity are observed.

Common questions about nitrate poisoning

How does nitrate get into the forage?

Nitrate is the form of nitrogen that the plant roots take up from the soil, and is transported to the leaves.

When do excess nitrates accumulate in the plant?

Excess nitrates accumulate in plants when they are stressed. Drought or hot dry winds put forage under water stress often resulting in nitrate accumulation. Damage caused by hail or frost impairs photosynthesis resulting in excess nitrates. Cool cloudy weather can also cause the problem.

When any of these conditions occur within a few days of harvest or grazing, the potential for nitrate poisoning exists. If the stress is removed and the plants recover, nitrate levels should return to normal within several days. If there is any doubt then test the feed.

Is there a stage of plant growth that is more prone to nitrate accumulation?

During initial growth, much of the nitrate taken up by the plant is used for root and shoot development. At this stage, the roots are able to take up more nitrate than is required and it accumulates in the stems and leaves of the plant. As the plant develops, the leaves of the plant are able to convert more nitrate into plant protein, therefore less "surplus" nitrate is found in the plant as it matures.

Are some plants more prone to accumulate nitrates?

Annual forage crops tend to accumulate greater amounts of nitrates than perennial forages. These crops are usually planted into well fertilized, manured or recently plowed grassland or pasture. Annual crops are also harvested at an early stage of development (milk to dough), when nitrate content is highest. Nitrate concentrations vary in different parts of the plant. The highest levels are found in the lower stems. Concentrations in the leaves and flowers are lower and the seeds or grain kernels are usually nitrate free.

Specific species can become nitrate accumulators if certain conditions exist. The common problem crops and weed species are in Table 1.

Does plant injury by hail for frost increase nitrate levels?

Crops hurt by frost or hail have a reduced photosynthesis capacity. After a frost or hail, the roots are usually unaffected and are able to supply the same amount of nitrate

Table 1. Common crop and weed species problems

Agricultural crops		Weeds	
barley greenfeed	beet tops	bull thistle	Canada thistle
wheat greenfeed	flax	fire weed	kochia
oat greenfeed	sugar beet tops	lambs quarters	mustards
rye greenfeed	sorghum	nightshade	pigweed
canola plants		Russian thistle	millet
		white ragweed	smartweed
		wild sunflower	

to the upper plant as prior to the injury. The upper plant is not able to use the nitrate as efficiently and it accumulates in the stem and leaves.

Nitrate levels remain high until new tissue growth is able to utilize the nitrate that is present. If the plant dies or is harvested, the accumulated nitrate stays in the plant material. It does not disappear with time.

What levels of nitrate are safe to feed?

Nitrate levels may be reported in three different ways depending on the analytical procedure used. The results may be reported as nitrate (NO_3), nitrate nitrogen (NO_3-N) or potassium nitrate (KNO_3). Be sure you know which method was used before trying to interpret the results. Refer to Table 2.

When is the best time to cut injured or damaged crops?

Nitrates accumulate with time in an injured or damaged crop. Injury to a plant can be from hail, frost, or other forms of physical damage that reduces photosynthesis.

It is best to cut or harvest the crop as soon as possible after damage. Nitrate will accumulate in a plant as long as it is taking up more nitrate than it can convert to protein.

What other factors will affect plant nitrate level?

Soil nitrogen levels greatly influence plant nitrate content. Large applications of nitrogen fertilizer or manure increase soil nitrate and thus the nitrate available to the plant.

Herbicide application may disrupt or interfere with normal plant function, such as photosynthesis or nutrient movement within the plant. This may result in nitrate accumulation.

Are all ruminants equally affected by high nitrate levels?

Ruminants have different capacities to convert nitrate into nitrite and finally to ammonia. Sheep have the highest tolerance to nitrates, because they have the greatest capability of all ruminants to convert methemoglobin back to hemoglobin. Cattle have the lowest capability and therefore are at greatest risk. The ability of individual animals to tolerate nitrates in feed is variable, which complicates the determination of a safe level of nitrate in a feed.

An animal in good body condition, receiving a diet that meets daily nutrient requirements is able to convert nitrate to nitrite and finally to ammonia more efficiently than an animal that is inadequately fed or in poor condition. Animals in poor condition, even if being well fed, have more trouble converting nitrite to ammonia.

What is the safest way to introduce cattle to graze a damaged crop?

Be sure that the animals are well fed before grazing the damaged crop. On the first day, let the animals eat from one-half to one hour and then remove them from the area. The idea is to slowly get the animals accustomed to the crop so that they can become less affected by the nitrate that is present. Eventually the animals can be left on the pasture full time. It will take five to seven days for the animals to become adjusted to the new feed. A

Table 2. Method of nitrate analysis and data reporting

Category	% NO_3	% NO_3-N	% KNO_3	Remarks
1	0.5	0.12	0.81	Generally safe
2	0.5 - 1.0	0.12 - 0.23	0.81 - 1.63	Caution
3	1.0	0.23	1.63	High nitrate problems

The values quoted above are on a dry (moisture free) basis.
Note: In category 2, some subclinical symptoms may appear.
In category 3, death losses and abortions can occur.

sample of the feed should be taken three or four days after the damage has occurred and tested for nitrate content to find out how severe the problem is. Peak nitrate levels should be present by this time.

What are some other sources of nitrates?

Nitrate from sources other than plant material can be poisonous. Water runoff from feedlot grounds can be high in nitrite. Nitrate and nitrite can be found in well water.

Some species of algae are nitrate producers and water contaminated with algae has been known to cause nitrate toxicity.

Non-feed commodities commonly found on the farm can also create nitrate toxicity problems. Ammonium nitrate and urea fertilizers have been implicated in poisoning cases. As cattle graze pastures, or forage around buildings, animals will locate fertilizer spills and quickly consume the material.

Can animals adjust to high nitrate feeds?

It is the rumen microbes not the animal that adjust to high nitrate feeds. Rumen microbes are responsible for the conversion of nitrate to nitrite and finally to ammonia. The microbes are able to adapt to a constant level of nitrate in the feed and make the nitrate conversion cycle more efficient. It takes three to five days for the microbes to adjust to the new rumen conditions and once adjusted the conversion increases in capacity by three to five times (above normal levels). During the adjustment period, some of the microbes will die off and the rate of digestion slows down. Once the microbial populations return to normal levels, digestion rates return to normal. Over time, rumen microbes do adjust to higher nitrate content in feeds, increase their survivability, and are able to function well in the new environment. This is why an adapted animal is able to handle higher levels of nitrate in a diet, but this does not make it easier to determine what is safe.

If animals are abruptly switched from a low nitrate level to a higher level, a buildup of nitrates can be expected before the microbes become adapted. Therefore, rotational grazing of animals or changing winter feeds that contain different nitrate levels may put the animals at risk. It is important to provide a ration that contains a relatively constant amount of nitrate.

Animals that are accustomed or adapted to a ration that contains nitrate can quickly pass this adaptability to animals that are held in close physical proximity (eg. in the next pen) within 2-3 days. The mechanism is not known, but it does occur.

What influences an animal's ability to tolerate nitrates?

The rate of feed intake and type of forage have a major influence on an animal's ability to withstand high levels of nitrites. The faster an animal consumes feed containing nitrates, the faster the rate of nitrate release. A dry hay contains less water than a fresh forage and is consumed more quickly (on a dry basis). Also, nitrate is released from a dry hay more rapidly into the rumen than from a fresh forage because many cell walls in the hay are reptured during drying, allowing for a rapid release of cell contents. Thirty per cent of the nitrate in a fresh forage is released in twenty minutes while eighty per cent of the nitrate is released from a dry hay in the same time period.

Does baling or ensiling reduce nitrate levels in feeds?

Research from the United States indicates that nitrate levels can be reduced by the ensiling process. However this cannot occur without a drop in the quality of the silage. The cost of reduced silage quality is greater than managing the nitrate problem in a different manner.

Crops ensiled with a high soluble sugar content (eg. cereal grains) have a rapid fermentation process. The rapid drop in pH does not promote rapid degradation of nitrate during the ensiling. Checking silage nitrate levels when the pit is being filled, usually provides an accurate indication of what the nitrate level will be later on.

Round bale greenfeed, if baled too moist (18-20% moisture will heat. The nitrate present in the feed may be converted to nitrites by the microbial action that causes heating. Nitrites in a feed are ten times more toxic than nitrates.

Summary

Nitrates are more likely to accumulate in annual forages than in perennial crops. Nitrates are a concern immediately following a period of drought or wet, dull weather.

The risk of nitrate toxicity can be reduced, but not eliminated, by taking the following steps:

1. Dilute the nitrate content of the total ration by feeding a combination of low and high nitrate feeds.
2. Feed the ration in two or three meals per day rather than just one meal per day.
3. Allow cattle to adjust to low levels of nitrate before increasing the nitrate content of the ration.
4. Ensure that livestock are being fed a balanced ration for the level of production that is expected.

Most feeds that contain nitrate can be fed to cattle if managed properly. Feed testing is essential in

determining what forages are safe and how to mix different
forages and grains to provide a safe ration. The costs of feed testing are considerably less than the loss of a single animal.

The accumulation of nitrate in plants does not necessarily mean that a problem will occur. Knowing how to manage the harvesting and feeding of a feed that contains nitrate will reduce possible problems in your livestock operation.

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